Functional Requirement Specification

Project X Low Energy Beam Transport Section

Prepared by: Lionel Prost	Fermilab	lprost@fnal.gov
Approved by: V. Lebedev, CW Linac Scientist	Fermilab AD	
Approved by: R. Stanek, PXIE Lead Engineer	Fermilab Directorate	
Approved by: S. Nagaitsev, Project Scientist	Fermilab Project X	
Approved by: M. Kaducak, Project X Project Engineer	Fermilab Project X	
Approved by: S. Holmes, Project X Project Manager	Fermilab Project X	

Revision History

Revision	Date	Section No.	Revision Description
0	1/3/2012	All	Initial Release.
1	7/19/2012	5	Added DocDB # for PXIE FRS
2	7/19/2012	5	Corrected DocDB number Reference to RFQ FRS

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1. Introduction:

Project X is a high intensity proton facility conceived to support a world-leading physics program at Fermilab.[1] Project X will provide high intensity beams for neutrino, kaon, muon, and nuclei based experiments and for studies supporting energy applications. The Project X Injector Experiment (PXIE) will be a prototype Front End linear accelerator,[2] that will validate the concept for the Project X front end, thereby minimizing a large portion of the technical risk within Project X.

The PXIE Low Energy Beam Transport (LEBT) section accepts the beam as it exits the Ion Source assembly and delivers it to the RFQ with the proper beam parameters. This specification includes the beam, vacuum, chopper and machine protection requirements, and interfaces to interconnecting equipment and adjacent beam line elements.

2. Scope:

The PXIE LEBT includes all of the beam line components necessary to transport, chop, and control the beam from the exit of the Ion Source assembly to the entrance of the RFQ. The overall layout of the PXIE components is shown in Figure 1.
In addition, the LEBT shall:

- Serve as the primary sub-system for machine protection by preventing the beam to propagate downstream.
- Allow for pulsed beam operation during commissioning of the downstream beam line.

Machine protection and pulsed beam operation are achieved via the chopper assembly that comprises a kicker followed by an absorber. For machine protection, the beam is diverted onto the absorber with the chopper kicker when a fault is detected. Similarly, beam pulses are obtained by power cycling the chopper kicker, alternatively diverting the beam onto the absorber or letting the beam pass. Note that the final time structure of the beam is realized in the Medium Energy Beam Transport (MEBT). However, provision shall be made for the chopper assembly, in particular the kicker, to be capable of delivering high frequency beam pulses hence providing an additional stage for the realization of the appropriate bunch pattern downstream.

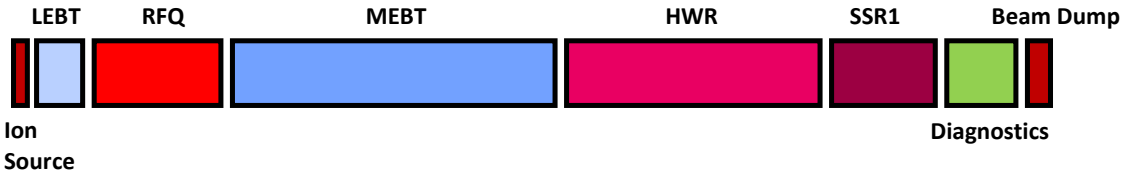

FIGURE 1: Major Subsystem in the PXIE Linac

Finally, the LEBT includes various diagnostics to characterize and tune the beam.

3. Key Assumptions, Interfaces & Constraints:

The LEBT will be installed initially in the PXIE facility. For Project X, the LEBT has to accommodate two ion sources (not running concurrently) and consequently needs to include a slow switching dipole magnet. On the other hand, only one ion source is incorporated in the PXIE front-end design. Nevertheless, a switching dipole is included in the PXIE LEBT section in order to validate its design.
The LEBT will conform to FNAL Engineering[5] and ES&H Standards.[6] All interfaces (e.g. power, instrumentation, vacuum) will be further discussed and agreed upon by the PXIE Project Scientist.

4. Requirements

Table 2. LEBT Requirements

Beam		
	Ion type	H^-
	Input kinetic energy	30 keV
	Output kinetic energy	30 keV
	Kinetic energy stability	0.5% RMS
	Nominal beam current	5 mA
	Maximum beam current	10 mA
	Beam current stability [for frequencies f > 1 Hz (ripples)]	±5%
	Duty factor	100%
	Input transverse emittance** over 1-10 mA current range	< 0.2 mm mrad
	Output transverse emittance** over 1-10 mA current range	< 0.25 mm mrad
	Beam loss outside gaps (i.e. un-chopped beam)	< 10%
Uptime		
	Turn-on time (after source switch e.g.: tuning)	< 2 hours
Chopper		
	Extinction ratio	10^{-4}
	Rise/fall time (10% - 90%)	< 100 nsec
	Single pulse length (> 90% of maximum intensity)	1 μsec - DC
	Maximum pulsing frequency #	1 MHz E
Machine protection		
	Beam shut-off time†	< 1 μs
	Beam stop insertion time (after fault detection)	< 1 sec
Vacuum		
	Max. Pressure	$\leq 10^{-6}$ torr
	Gate valve before the switching magnet	
	Gas flow to RFQ (beam on)	$< 2\times10^{-3}$ torr l s^{-1}

1 to 100 μsec beam pulses at 10-60 Hz will be used for commissioning, troubleshooting and machine tuning

E If 'pre-chopping' becomes necessary for realizing the required bunch patterns downstream

† This is the time it takes for the beam to be diverted onto the absorber with the chopper kicker once a fault is detected

** The rms emittance is defined using the second moments of the particle distribution in phase space (e.g.: x-x') as follows: $\varepsilon_x = \left(\overline{x^2}\,\overline{x'^2} - \overline{xx'}^2\right)^{1/2}$. In modeling, it is based on 100% of particles; in experiments, it may be based on a truncated intensity (95-100%) to reduce the effect of far tails on the calculated emittance value.

5. References:

Documents with reference numbers listed are in the Project X DocDB: http://projectx-docdb.fnal.gov

[1] Project X Functional Requirements Specification
Document #: Project-X-doc-658

[2] Project X Injector Experiment Functional Requirements Specification
Document #: Project-X-doc-980

[3] PXIE Ion Source Functional Requirements Specification
Document #: Project-X-doc-968

[4] PXIE RFQ Functional Requirements Specification
Document #: Project-X-doc-894

[5] Fermilab Engineering Manual
http://www.fnal.gov/directorate/documents/FNAL_Engineering_Manual_REVISED_070810.pdf

[6] Fermilab ES&H Manual
http://www-esh.fnal.gov/pls/default/esh_home_page.page?this_page=15053